

METHODS OF CENSUSING RED FOX (*VULPES VULPES*)  
POPULATIONS

METODI DI CENSIMENTO DELLA VOLPE (*VULPES VULPES*)

JUAN FRANCISCO BELTRÁN(\*), MIGUEL DELIBES (\*) & JAIME R. RAU(\*\*)

ABSTRACT

Estimating absolute or relative numbers in red fox populations is not an easy task. Although a range of methods has been described, neither an optimal nor a universally accepted technique has been found. Moreover, none has been tested on populations of known size. We reviewed the efficiency of fourteen indices of fox abundance classified into two groups: (a) methods where individuals are captured and marked, which include ear tagging or similar conspicuous markings, toe clipping, radioactive tagging of faeces, radio-tracking, and statistics from hunting and trapping; (b) methods not requiring capture, which include both direct methods (nocturnal counts, unsystematic observations, and drive censuses), and indirect methods (den counts, transects for track, scat counts, and scent stations). As a rule, statistics are rarely applicable to populations estimates. Methods involving capture are expensive but provide more accurate estimates than the second group of indices, which are not suitable for paired comparisons from one year to another. Management and wildlife specialists should have in mind such restrictions when considering their goals and the required level of accuracy. Finally, we recommend the simultaneous utilization and comparison of several methods (one from each group, as proposed in a double sampling strategy) for optimum evaluations.

Key words: Census methods, *Vulpes vulpes*, Canidae.

RIASSUNTO

La valutazione della consistenza di una popolazione di Volpe, mediante censimenti assoluti o relativi, è di difficile soluzione. Tra i diversi metodi di conteggio impiegati, nessuno si è rivelato ottimale e universale. Tuttavia nessuno è stato utilizzato per popolazioni di consistenza nota. Qui esaminiamo la validità di 14 metodi impiegati per il calcolo di indici di abbondanza, ripartendoli in due gruppi: (a) metodi che implicano la cattura e il marcamento degli animali mediante marche auricolari o contrassegni similari, amputazione delle falangi, radioisotopi rilevabili nelle feci, collari radiotelemetrici e metodi che si basano sulle statistiche venatorie e sui trappolaggi; (b) metodi che non richiedono la cattura degli animali e che riguardano sia rilevamenti diretti (conteggio notturno, avvistamenti casuali, censimento in battuta), sia indiretti (conteggio delle tane, conteggio delle impronte e delle feci su percorsi definiti, stazioni odorifere). Raramente l'analisi statistica è applicabile alle stime della consistenza delle popolazioni. I metodi che implicano la cattura degli animali sono molto impegnativi in termini di tempo e costi, ma forniscono stime più accurate rispetto a quelli del secondo gruppo che non sono adatti per la comparazione dei dati da un anno all'altro. Questi limiti vanno attentamente considerati in relazione alle finalità e al grado di precisione che si intende raggiungere. Noi suggeriamo l'impiego simultaneo di più metodi di censimento (almeno uno per ciascun gruppo), per una comparazione incrociata dei dati e per ottenere una stima corretta della consistenza.

Parole chiave: Metodi di censimento, *Vulpes vulpes*, Canidae.

(\*) Estación Biológica de Doñana, CSIC. Apdo. 1056, E-41080 Sevilla, Spain

(\*\*) Dpto. Ciencias Exactas y Naturales, IPO, Casilla 933, Osorno, Chile

## INTRODUCTION

We will use the term census in a broad sense. Censuses are commonly aimed not so much at determining the actual numbers of individuals in a population (Overton, 1971; Davis and Winstead, 1980), but rather at estimating an index of abundance from a certain sampling size. This allows the comparison of areas on a temporal and/or spatial basis. In any case the proposed target is not easily achievable and it is expensive. No one method, among the many described in the literature, can be considered as the best or the one always yielding optimal results. All of them have limitations and most of the assumptions upon which sampling procedures are based are not usually met (Rau, 1988; Estes and Jameson, 1988). Moreover, there is hardly a simple case where indexes have been compared using populations of known size (e.g. Davis and Winstead, 1980).

Two other aspects of censusing methods deserve more attention than they are commonly given. Firstly, the level of accuracy (i.e. resolution) given by censusing is often below acceptable limits. Rolley (1987) studying this subject in bobcats (*Lynx rufus*) - a medium sized carnivore - stated that no single technique has proven sensitive enough for detecting changes smaller than 10-25% within a population. Thus, the effect of any factor potentially regulating the population could not likely be detected unless it would exceed this percentage. Secondly, the relationship between cost of censusing and results obtained is often disregarded by the researcher. Usually, the most familiar method has the highest probability of being chosen. Specialists interested in estimating Red fox abundance at a given

Tab. 1 – Summary of methods reviewed in this paper for estimating population size in *Vulpes vulpes*.

---

### A. - METHODS REQUIRING CAPTURE

- A.1. - Capture-mark-recapture methods (CMR)
  - 1. - Conspicuous tagging (ear-tagging, collaring etc.)
  - 2. - Toe-clipping
  - 3. - Radioactive marking of faeces
- A.2. - Home range size
- A.3. - Statistics
  - 5. - Hunting Indicator of Population Density (HIPD)
  - 6. - Trap-lines

### B. - METHODS WITHOUT CAPTURE

- B.1. - Direct methods
    - 7. - Night counts
    - 8. - Drive census
    - 9. - Non-systematic observations (sightings)
  - B.2. - indirect methods
    - 10. - Den counts
    - 11. - Track counts
    - 12. - Scat counts
    - 13. - Scent-station lines
    - 14. - Other ("a posteriori")
-

place and time need to know, at least crudely, both the input required and results obtainable from the available methods. Only in this way one can choose the most suitable method as a compromise between his needs (i.e. goals, aims) and his resource availability (i.e. money, helpers, etc.).

This paper is aimed at revising fourteen different methods that have been used for estimating Red fox populations either by us at the Doñana Biological Reserve (DBR) (Rau et al., 1985a), or by other authors in other countries. We include methods applied to other carnivores which can be adapted for fox census, and we outline the principal advantages and limitations of each.

## METHODS REQUIRING CAPTURE

From a practical perspective, methods for estimating Red fox populations can be classified into those that require the capture of individuals and those that do not (Tab. 1). Among the first group, there are obvious differences if the researcher himself captures the animals and releases them afterwards (capture-mark-recapture modified), or if data are obtained from captures carried out with a wider range of techniques (e.g. hunting and trapping).

### CAPTURE-MARK-RECAPTURE METHODS (CMR)

Because it allows **many** possibilities, this methodology has been given a lot of attention in the literature (e.g. Otis et al., 1978; Seber, 1982; White et al., 1982; Montgomery, 1987). Nevertheless, foxes are difficult to capture and even more to recapture, so that this method cannot be strictly applied. Instead, foxes should be captured and marked with different systems, which allow to identify or detect them from a distance (Stonehouse, 1978). The theoretical basis of CMR methods has a simple formulation: in a population of  $N$  individuals,  $M$  individuals are captured and marked; from a subsequent sample of " $n$ " individuals of the same population, " $m$ " marked individuals are found. The size of the population is then given by:

$$N = (M \cdot n) / m$$

The principal assumptions are: a) the population is closed (Lincoln-Petersen or Schnabel procedures can then be applied, e.g. Todd et al., 1982, though estimators for open populations such as those of Bailey, and Jolly-Seber are also available, e.g. Clark, 1972; Caughley, 1977); b) individuals are equally catchable, that is, the sample is homogeneously distributed among the population, both before capturing and after marking. The socio-spatial organization of foxes - as of other carnivores - invalidates the second assumption, and correction factors are necessary (Burnham and Overton, 1979; Pollock, 1982; Pollock et al., 1985, among others). An additional problem concerning this methodology is the difficulty of estimating the capture area, since the range of movements of individuals is often unknown. Radio-tracking can usually solve this problem (Greenwood et al., 1985; Kufeld et al., 1987; Babb and Kennedy, 1989).

CMR methods yield absolute estimates of density (number individuals/ area). As a rule, any censusing method could yield an estimate of the whole population, though it seems more appropriate - see below transect methods - to consider census results only as relative abundance estimates (Kolb, 1982; Eberhardt and Simmons, 1987).

CMR methods are potentially useful for sampling foxes if the underlying assumptions can be met.

### CONSPICUOUS TAGGING

Coloured tags and other marks that are difficult to see at night are not suitable for the Red fox, given its nocturnal or crepuscular activity. However, reflecting marks (Macdonald, 1987) which can be lit up from a distance, can be a very useful aid. This method requires open places frequented by foxes and the possibility for a researcher to cover as large an area as possible. At Doñana Biological Reserve, a 7,000 hectares study area in the Doñana National Park, Southwestern Spain, we marked foxes with radio-transmitters fitted to reflecting collars (Deibes and Beltrán, 1986), but the scarcity of observations (see below Sightings) due to thick shrubs made this method unusable. Other authors have ear-tagged foxes, but unless a correction is made for tag losses, this method may give erroneous results (Hurbert et al., 1976; Englund, 1980).

### TOE-CLIPPING

Wildlife specialists have used controlled finger amputations in coyotes (*Canis latrans*) in order to recognize their tracks (Andelt, 1981; Henshaw, 1981). The population can be estimated fairly accurately from the ratio of "normal" to "amputated" animal tracks, but this method is restricted to places and circumstances where tracks can easily be detected (snow or sand transects, dirt roads, etc.). A surgical operation may also be considered unethical on cruelty grounds and because the animal is left with a permanent handicap. It has the advantage that several population categories can be marked (by sex, by age, individually, etc.), according to the number and position of the amputated fingers, which allows more reliable and structured estimations.

### RADIOACTIVE MARKING OF FAECES

Marking of faeces with radioactive isotopes has been in use for some twenty years to estimate population size in quite a number of species. It was first employed to census fox populations (Nellis et al., 1967) and then other carnivores, with success (Conner and Labisky, 1985; Crabtree et al., 1985). Once captured, animals are given an intramuscular or intraperitoneal injection (5-100 microcuries) of one or several combined radioactive isotopes, usually Zn<sup>65</sup> and Cd<sup>109</sup>, but also Ce<sup>144</sup>, Cs<sup>134</sup>, Co<sup>60</sup> and Mn<sup>154</sup>. Isotopes are chosen for their low radio-toxicity (most of them emit gamma radiations), a mean physical and biological life adjusted

to study period (ranging from some weeks to years), and the major route of elimination of the isotopes through faeces, among other characteristics (Pelton and Marcum, 1977; Kruuk et al., 1980). If five of the above cited isotopes were injected singly or in combination with any other, up to 15 different individuals or cohorts of a wild population could be marked, making it possible to carry out simultaneous sampling of intrapopulation differences in habitat use, food preferences, marking behaviour, etc. (Sibly and Smith; 1985).

A major obstacle to this technique, besides the correct identification of scats, is the way territory tenure systems by different individuals can influence detectability of faeces. For instance, a territorial fox may use more conspicuous places to mark than a transient one; males may mark in different places than females and more frequently, etc. Once more, radio-tracking would be an ideal complementary tool (Mitchell-Jones et al., 1984; Conner and Labisky, 1985). Considering its advantages, radioactive marking of faeces provides a very good approach to meeting the assumptions of CMR methodology because of: a) the statistical independence of the marking and recapturing phases of the technique, b) the relatively small selectivity in recapture (i.e. low degree of heterogeneity), and c) the relatively high recapture probability,

#### HOME RANGE SIZE

This is probably the most common method applied to carnivore studies, Our knowledge of these elusive mammals has dramatically increased with the development of radio-telemetry devices (Patric et al., 1982; Kenward, 1987).

Density estimates (D) are obtained from the equation:

$$D = 1/H$$

where H is the mean individual home range size population, which can be evaluated by various algorithms (Stuwe and Blohowiak, 1989).

This method estimates minimum yield values (i.e. it underestimates the population), because it is assumed that each home range is used exclusively by one animal. This is not always true. Foxes live in social groups whose sizes vary in relation to the abundance and spatial distribution of resources (Voigt and Macdonald, 1984; Doncaster and Macdonald, 1991). Thus, estimates based on this method must be treated with caution, particularly when sample biases are suspected (Laundré and Keller, 1984).

In our study area, Red foxes were radiotracked and sampled with other census methods at the same time in order to evaluate and improve different techniques. Besides the difficulty noted above, we found that this method could be misleading because the seasonal variations observed in home range size were not associated with changes in absolute density (Rau, 1988).

#### HUNTING AND TRAPPING LINES

The number of foxes hunted during sport, management or bounty trials over a whole country, state, etc. provides sufficient information to estimate HIPD

abundance index (Hunting Indicator of Population Density, Zimen, 1980). The HIPD or similar indices show a high degree of reliability for determining population trends over large areas. Voigt (1987) (see also Kolb and Hewson, 1980; Kolb, 1982) has pointed out that monitoring of hunting or trapping captures is likely to provide the best estimates of temporal variation in the population when the data come from large enough areas, despite some non-negligible problems (see Smith et al., 1984). Probably one of the most significant handicaps is in the way how hunting and trapping data are collected, being country dependent. A good idea of the quality of information potentially obtainable is to be found in the fur sales tables of Novak et al. (1987). Other notable studies are described in Jenkins et al. (1981), and the classic paper by Elton and Nicholson (1942).

Zimen (1980) recorded a close association between temporal evolution of the HIPD and abundance of rabid foxes in the samples. An index could thus be constructed a posteriori (see below) with adequate adjustments, to predict fox population trends from the rabid foxes hunted.

We remark, as a conclusion to this second category of methods requiring capture of animals, the relatively low cost involved if suitable data (i.e. survey plans and registration) are collected, and the high reliability of these methods, although some correction factors (e.g. capture per unit effort when hunting efficiency, fur price, and other variables affect the sample), must be considered for interpreting the data.

## METHODS WITHOUT CAPTURE

### NIGHT COUNTS

The protocol of this method can be summarized as follows: using a vehicle equipped with a moveable spotlight, at least two persons make a transect survey (40 km in Artois, 1981) at a constant speed (10 km/hour), with replications (2-5) of the transect on consecutive nights.

The method was first designed to census lagomorph populations, later being applied to carnivores in open habitats (Waser, 1980). Artois (1981), and Schantz and Liberg (1982), among others (see also Pandolfi et al., 1991), have successfully adapted the method to estimate red fox populations. Lloyd (1980) described how this method could be used in forested areas well intersected by roads: "In such places foxes in fields adjoining roads are not disturbed by passing cars and sightings can be made at fixed intervals along the roadside ...".

Nevertheless, several factors should be taken into account for a standardized method. For example, Artois (1981) found the most favourable conditions to census were between 21.00 - 03.00 at the newmoon, with high cloud cover, and no wind. Other factors he considered were the annual cycle of vegetative cover and the structure of the fox population. An autumn census could be used to detect the increase in fox numbers due to recruitment and dispersal, while an early spring estimate would comprise largely breeding individuals.

Night counts can be converted to estimates of absolute density if: a) the range of visibility is tested each time, and b) plots of a known area are sampled instead of a transect line (Schantz and Liberg, 1982). Time units (foxes counted/hour) are preferable for comparing areas that differ in habitat composition. Another variation on the procedure is to partition a line transect into habitat segments. This option could also improve possibilities of data analysis.

As for any line transect procedure (Burnham et al., 1980), a basic rule is to standardize the sources of variation associated with sampling effort (some mentioned above, also the experience of staff, above all if night counts are performed for several species simultaneously, e.g. predators and prey). Clearly, one of the most significant problems with night counts is the great variety of factors influencing the use of space and time by animals. For example, one could ask: What percentage of the fox population is really counted, (i.e. detectable) by spotlighting? A suitable correction factor has been calculated by radio-tracking red foxes and determining the mean percentage of time spent by several individuals in open habitats, where they were detectable by spotlighting (Schantz and Liberg, 1982).

#### DRIVE CENSUS

The animals are driven into a delimited area by trained people, sometimes assisted by hounds, and counted as they cross the observer's line. Overton (1971) cited a simplified version of this method by replacing the observer's line with a sand transect (or other soft material) from which the animal tracks could later be identified.

This method can be used successfully in woodland or dense vegetation cover, such Mediterranean shrubland. For example, Telleria and Sáez-Royuela (1984) estimated densities of fox and roe deer (*Capreolus capreolus*) by sampling in plots of 75 hectares of oak hardwoods (*Quercus robur*). However, the effort required for a suitable sample size (these authors conducted 35 drive censuses), and also the time spent in organizing a sufficient number of helpers (observers, beaters, and their hounds, etc.), should be considered when planning a drive census. These problems were resolved for Sáez-Royuela and Telleria (1988) who were able to profit from hundreds of drives organized for hunting. Among the advantages of the drive census are its reliability and the possibility to obtain simultaneous data on other animals, particularly game species. It is important to note that the accuracy of the results will be positively correlated with the number of beaters, and negatively correlated with the size of area sampled (Telleria, 1986).

Undoubtedly, the degree of disturbance that the drive census involved must also be considered; this is probably not an ideal method to use in nature reserves.

In our experience, we have found a good approximation between results obtained from drive census out of the limits of Doñana National Park and those recorded from other density estimators previously developed for this area (see below), at about 1.7 foxes/km<sup>2</sup>.

## SIGHTINGS (NON-SYSTEMATIC OBSERVATIONS)

The basis of this method is to get a registration for any fox sighting in a given area. For the analysis of such data, sightings must be referred to unit effort such as the number of observers, time spent in the field, distance travelled, etc (Rau, 1988).

This is probably the simplest of all the available methods to estimate relative abundance of red foxes, being especially recommended for protected areas, or places where field work is in progress (research, vigilance, etc.). It implies many man/hours spent in the field. Allen and Sargeant (1975), and Harris and Rayner (1986a) employed sightings of foxes to calculate abundance indices. Nevertheless, the very simplicity of this methodology needs corrections in order to validate the results and to obtain realistic interpretations of the data. See for example Voigt's (1987) comments on the difficulties involved in defining the correspondence between a sighting index and an estimate of relative abundance.

We have been able to determine a suitable adjustment for our study area. Red fox sightings due to keepers, researchers, and visitors were corrected against observer numbers. Identification of animals with visual tags permitted us to calculate the percentage of re-sighting of any individual. Finally, simultaneous radio-tracking data were used to estimate probability of a fox-crossing dirt road or firebreak inside its home range, where it was most easily detectable in the field. Computing these factors, Rau (1988) obtained a fox abundance index with trends well accorded with the fox density in Doñana Biological Reserve as estimated by other more sophisticated methods.

The method's economy, simplicity, easy standardization, and good adjustment possibilities with other more reliable methods, which are also more expensive (in money and time), are good enough reasons for using a data base of fox sightings as a measure of population trends. This approach to density estimators has been named "double sampling" (Eberhardt and Simmons, 1987). Fox-sightings is only one of the possibilities (see below track counts), and can be applied to other species besides foxes.

## DEN COUNTS

Counts of breeding fox dens in late spring or summer depending on the study area (Lloyd, 1980), can be used to determine the absolute abundance of the species.

The literature on this subject is certainly not lacking. The classic work of Sargeant et al. (1975), profiting from the excellent visibility over their study area for counts of fox dens from an airplane, can be compared with counts accomplished on foot which requires more staff, field knowledge, etc. (Storm et al., 1976; Lindstrom, 1980; Hewson, 1986; Prigioni et al., 1991).

Probably the major advantage of censusing foxes by counting their breeding dens is the good level of accuracy obtained by this method. Sargeant et al. (1975) detected 84% of 270 fox families in their study area. Obviously, some information

has to be assumed such as the number of individuals per den, territory size of a fox family, etc. If the survey is carried out on foot, additional data can be registered such as food habits of cubs versus adults (Delibes and Mañiez, 1984), and competition with other species for den sites (Pigozzi, 1986). Den location also provides a good basis for further work such as capturing (Zoellick and Smith, 1986) and population management (Zimen, 1980; Hewson, 1986).

#### TRACK COUNTS IN PERMANENT TRANSECTS

Dirt roads, firebreaks, and other similar clearings are commonly used by foxes, for travelling, marking, or establishing their home range border (Sargeant, 1972; Fabrigoulé and Maurel, 1982; Maurel, 1983, among others). This pattern of space use is not a characteristic unique to red foxes. Pulliainen (1981) monitored annual fluctuations in relative abundance of four species of carnivores, the red fox included, by skiing along a permanent transect of 6 kilometers weekly during the snowy season (November to April). His results were enhanced by simultaneous observations on rodent activity and habitat preferences of the carnivores during a study period long enough - 13 consecutive winters - to describe predator-prey and community dynamics. This methodology has been used by Rau et al. (1985b) in Southwestern Spain (Doñana Biological Reserve) to estimate fox density by track counts on sand transects.

A basic assumption of this method is that a linear relation exists between the number of tracks (or other signs) detected and the relative abundance of the species. However, from our experience, this is not always the case. From simultaneous radio-tracking of foxes and surveying of a 1.2 km long sand transect, a conversion factor was obtained of track/km to foxes/km (Servín et al., 1987). Each fox crossed the transect 3 times on average in each 24 hour cycle. However, the location of the transect greatly influenced the results.

Stephenson (1986), and Schwartz and Becker (1988) have been involved for several years in developing simple techniques to estimate population trends in *Lynx canadensis*. Their design is a double sampling procedure: simultaneous monitoring of lynx tracks in snow transects and radio-tracking of individuals during 24-48 hours. Movements of marked lynxes constituting a random subset of the population were analysed by various methods, including simulation (Becker in press, in Schwartz and Becker, 1988).

#### SCAT COUNTS IN PERMANENT TRANSECTS

The use of scat counts to determine fox abundance has some similarity with the previous method: a) sampling is carried out along delimited transects, if possible permanent in location; b) a stratified sampling design is also preferred in order to avoid the effects on population trends of seasonal changes in habitat use by foxes. The scat count procedure, however, requires special correction factors (see below).

Probably no other method has such long tradition in the estimation of species abundance (Kolb and Hewson, 1980; Putman, 1984). Rau et al. (1985a and b)

adapted Taylor and Williams' (1956) method to a permanent plot in order to compute the absolute density of foxes from their faeces.

The main premises of this methodology are as follows. (A) The age of collected faeces is known. For example, if samples are taken monthly, the first month must be disregarded and considered as cleaning or preparation of the transect. (B) Rates of defecation and faeces decomposition are known (see for example Litvaitis and Mautz, 1975; Andelt and Andelt, 1984), as well as their temporal variation. (C) Ail faeces are detected and registered. (D) Faeces are randomly distributed. (E) Population is stable while sampling is carried out.

Few of these premises are met in practice. Regarding defecation rates, a test with foxes in captivity showed that the number of scats produced was related to the nature of the food ingested (Rau, 1988), ranging from 6 or more scats/24 hours when fruits and whole rabbits were available, to only 2-3 scats/24 hr. when carrion was eaten. Similarly, the spatial distribution of faeces is known to be highly contagious, mainly due to its role in territorial marking (Macdonald, 1980), and this affects the sample size needed (Overton, 1971). Since correction factors are crucial to the final density estimates, it is recommended that the number of faeces be used only as indices of relative abundance (Kolb, 1982; Rau, 1988).

## SCENT STATION INDEX

Originally designed in North America to estimate the relative abundance of species of foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), the use of scent stations has been employed for a number of years and on a large scale to detect changes in population trends of other carnivores (Knowlton and Tzilkowski, 1981; Corner et al., 1983). Linhart and Knowlton (1975), and Roughton and Sweeny (1982) helped in standardizing this field technique, including procedures for analysis of data.

The index is based on response to an olfactory stimulus, which is deposited at the center of a circle of sand or other soft material, 0.9-1 m in diameter. This scent has also been standardized (Fatty Acid Scent, Roughton and Sweeny, 1982), but bobcat urine and that of other animals have been successfully used (Rau et al., 1985a; Martin and Fagre, 1988). A variable number of scent stations are spaced some hundred metres apart to form a transect, the true sampling unit. Each transect must be spaced far enough from the next (from one to several kilometers) to minimize the probability of an animal visiting more than one line of stations in a night.

The location and the spacing of stations and transects rely on the pattern of space use (home range and daily distances travelled) and on factors influencing the mobility of animals in the study area (cover, prey availability, pathways, etc.). However no precise protocol has been yet described. Finally, each transect must be activated for a single night per month or per season. Efforts must be made to sampling as instantaneously as possible. Usually it is better to increase the number of stations per transect or the number of transects than to repeat the sampling for two or more consecutive nights. However, repeated samplings are recommended

by Conner et al. (1983) as a modification to establish patterns of abundance for species that are present at a low density (additional remarks below).

When is the optimum moment to sample the fox population? Most authors agree that the best time is when the population reaches its maximum density, i.e. in the autumn, following recruitment and dispersal. However some planning improvements should also be considered in order to obtain complementary information, such as habitat sampling and replication procedures (Humphrey and Zinn, 1982; Hurlbert, 1984).

The scent station index is useful for detecting annual trends in relative abundance of the species. Several species can be monitored simultaneously but interspecific comparisons cannot be made with this method. As mentioned above, the major limitation of the scent station technique is its dependence on the degree of mobility of species and related factors (among the most conspicuous is habituation to transects, Robson and Humphrey, 1985). Moreover, there is a reasonable basis for assuming a curvilinear relationship between species density and the computed index (see Roughton and Sweeny, 1985). This has two important consequences: a) there is a threshold density of animals to be detected as visits to the station lines, and b) abundance estimates in areas with different habitat composition are difficult to compare.

Conner et al. (1983), in one of the few published papers contrasting estimates from different methods (radioisotopes, trapping, scat counts, radio-tracking, and scent station index; see also Lindström, 1982), concluded by noting the coincidence between methods used to estimate population trends in many species of carnivores. Scent station indices accurately reflected trends in bobcat, raccoon and gray fox abundance, but were ineffective for opossum due to its erratic visitation pattern (Conner et al., 1983).

A recent contribution to population estimates is currently being carried out by Novaro et al. (pers. com.) to *Pseudalopex culpaeus* and *P. griseus*, in Patagonia (Argentina). Their work address an interesting application of the formulation in Seber (1982), and Eberhardt (1982): absolute density is obtained from an index measuring relative abundance (for instance, the scent station index) employed before and after removal of a known number of individuals from the fox population.

#### METHODS "A POSTERIORI"

This last section comprises a variety of methodologies based on the good correlation observed between indirect indices and fox abundance in some well monitored areas. Once this correlation is established, fox abundance in other areas can be estimated from the same parameters. For example, Macdonaid et al. (1981) used a procedure for quantitative typification of habitats to generalize their estimates from study areas to the whole of Great Britain. More recently, Harris and Rayner (1986b, 1986c), estimated the abundance of urban foxes in some hundred cities from parameters such as human population size and social structure, industrial development, etc. Their models predicted the carrying capacity of

hundreds of British cities, subsequently validated by "ad hoc" studies (Harris and Smith, 1987).

The percentage of rabid foxes hunted is also a potentially good estimator of fox population trends, if adequate corrections are developed (Zimen, 1980).

It is clear that these approaches are open to new contributions.

## FINAL CONSIDERATIONS

Concluding this short review, we wish to remark some ideas in connection with two phases in the realization of fox censuses.

When planning a census and its goals, much thought should be given to choosing a method appropriate to: a) the characteristics of the study area (habitat, infrastructures including personnel, availability of dirt roads, etc); b) estimated efforts and expected results, c) the level of accuracy needed; and d) sample size design and complementary information required to achieve a correct interpretation of the data.

During the analysis and the discussion of results, it is recommended to compare estimates recorded simultaneously by different methods. If a double sampling design has been applied -perhaps including a capture-recapture method-, it will be easier to optimize the additional effort required during data collection for subsequent censuses. In our opinion, radio-tracking has proven to be a chameleontic tool in population estimation techniques. Correction factors and field trials have been improved with data from radio-tagged individuals, yielding higher accuracy and reliability in the estimates, which is a top priority in all our attempts to census populations.

## ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the kind invitation of the organizers to participate in the Primo Simposio Italiano sui Carnivori. Research on red foxes in DBR has been conducted as a part of project 944, financially supported by Consejo Superior de Investigaciones Científicas (CSIC) and Comisión Asesora de Investigación Científica y Técnica (CAICYT). One of the authors (Beltrán) holds a postdoctoral fellowship from CSIC; during the study Rau enjoyed a predoctoral grant from the Instituto de Cooperación Iberoamericana (ICI). We also thank the critical suggestions from L. Boitani and J.C. Blanco. A first English draft was kindly reviewed by N. Bustamante. We become specially indebted with C.P. Doncaster who accepted to read the manuscript and made useful style corrections.

## REFERENCES

- ALLEN, S.H. & SARGENT, A.B. 1975. A rural mail carrier index of North Dakota red foxes. *Wildl. Soc. Bull.* 3: 74-77.
- ANDELT, W.F. 1981. Toe-clipping coyotes: a reply. *J. Wildl. Manage.* 45: 1007-1009.
- ANDELT, W.F. & ANDELT, S.H. 1984. Diet bias in scat deposition-rate surveys of coyote density. *Wildl. Soc. Bull.* 12: 74-77.
- ARTOIS, M. 1981. Méthodes de dénombrement des populations de renard roux. *Bull. Mens. ONC.* 47: 23-32.
- BABB, J.G. & KENNEDY, M.L. 1989. An estimate of minimum density for coyotes in Western Tennessee. *J. Wildl. Manage.* 53: 186-188.

- BURNHAM, K.P. & OVERTON, W.S. 1979. Kobust estimation of population size when capture probabilities vary among animals. *Ecology* 60: 927-936.
- BURNHAM, K.P., ANDERSEN, D.R., LAAKE, J.L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72, 202 pp.
- CAUGHLEY, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, London, 234 pp.
- CLARK, P.W. 1972. Influence of jackrabbit density on coyote population change. *J. Wildl. Manage.* 36: 343-356.
- CONNER, M.C., LABISKY, R.F., PROGULSKE, D.R. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes and opossums. *Wildl. Soc. Bull.* 11: 146-152.
- CONNER, M.C. & LABISKY, R.F. 1985. Evaluation of radioisotope tagging for estimating abundance of raccoon populations. *J. Wildl. Manage.* 49 326-332.
- CRABTREE, R.L., BURTON, E.G., GARLAND, T.R., RICHARD, W.H. 1985. Carnivore studies: a new individual marking system. Abstracts of papers and posters IV<sup>th</sup> ITC, Edmonton, Alberta.
- DAVIS, D.E. (ed.) 1982. Handbook of census methods for terrestrial vertebrates. CRC Press, Inc., Florida, 397 pp.
- DAVIS, D.E. & WINSTEAD, R.L. 1980. Estimating the numbers of wildlife populations. In Schemnitz S.D. (ed.): *Wildlife Management Techniques Manual*. 221-245. Fourth Ed. The Wildlife Society. Washington.
- DELIBES, M. & MAÑEZ, M. 1984. Alimentación de una camada de zorros *Vulpes vulpes* (L.) en Castilla la Vieja. España. *Rev. Mus. Argentino de C.Nat. Bernardino Rivadavia e Insto. Nal. de Invest. de las C. Nat.* 13: 361-367.
- DELIBES, M. & BELTRÁN, J.F. 1986. Radio-tracking of six species of carnivores in Doñana National Park, SW Spain. *Mesogée* 42: 113-120.
- DONCASTER, C.P. & MACDONALD, D.W. 1991. Ecology and ranging behaviour of red foxes in the city of Oxford. In Prigioni C. (Ed.): *Atti I Simp. Ital. Carnivori. Hystrix*, (n.s.) 3 11-20.
- EBERHARDT, L.L. 1982. Calibrating and index by using removal data. *J. Wildl. Manage.* 46: 734-740.
- EBERHARDT, L.L. & SIMMONS, M.A. 1987. Calibrating population indices by double sampling. *J. Wddl. Manage.* 51: 665-675.
- ELTON, C.H. & NICHOLSON, M. 1942. The ten-year cycle in numbers of the lynx in Canada. *J. Anim. Ecol.* 11: 215-244.
- ENGLUND, J. 1980. Yearly variations of recovery and dispersal rates of fox cubs tagged in Swedish coniferous forest. In Zimen E. (ed.): *The red fox. Symposium on Behaviour and Ecology. Biogeografica*, 18: 195-207.
- ESTES, J.A. & JAMESON, R.J. 1988. A double-survey estimate for sighting probability of sea otters in California. *J. Wddl. Manage.* 52 70-76.
- FABRIGOUË, C. & MAUREL, D. 1982. Radio-tracking studies of foxes, movements related to their home range. A cognitive map hypothesis. *Quart. J. Exp. Psychol.* 34B: 195-208.
- GREENWOOD, R.J., SARGEANT, A.B., JOHNSON, D.H. 1985. Evaluation of mark-recapture for estimating striped skunk abundance. *J. Wildl. Manage.* 49: 332-340.
- HARRIS, S. & RAYNER, J.M.V. 1986a. Urban fox (*Vulpes vulpes*) population estimates and habitat requirements in several British cities. *J. Anim. Ecol.* 55: 575-591.
- HARRIS, S. & RAYNER, J.M.V. 1986b. Models for predicting urban fox (*Vulpes vulpes*) numbers in British cities and their application for rabies control. *J. Anim. Ecol.* 55: 593-603.
- HARRIS, S. & RAYNER, J.M.V. 1986c. A discriminant analysis of the current distribution of urban foxes (*Vulpes vulpes*) in Britain. *J. Anim. Ecol.* 55: 605-611.
- HARRIS, S. & SMITH, G.C. 1987. The use of sociological data to explain the distribution and numbers of urban foxes (*Vulpes wipex*) in England and Wales. *Symp. Zool. Soc. Lond.* 58: 313-328.
- HENSHAW, R.E. 1981. Toe-clipping coyotes for individual identification: a critique. *J. Wildl. Manage.* 45 1005-1007.
- HEWSON, R. 1986. Distribution and density of fox breeding dens and the effects of management. *J. Appl. Ecol.* 23: 531-538.
- HUMPHREY, S.R. & ZINN, T.L. 1982. Seasonal habitat use by river otters and Everglades mink in Florida. *J. Wddl. Manage.* 46: 375-381.
- HURBERT, G.F., STORM, G.L., PHILIPS, R.L., ANDREWS, R.D. 1976. Ear tag loss in red foxes. *J. Wildl. Manage.* 40: 164-167.
- HURLBERT, S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54: 187-211.

- JENKINS, J.H., PROVOST, E.E., FENDLEY, T.T., MONROE J.R., BRISBIN, I.L., LENARZ, M.S. 1981. Techniques and problems associated with consecutive twenty-five year furbearer trapline census. In Blum L.G. and Escherich P.C. (eds.): Bobcat Res. Conf. Proc., Nat. Wildl. Fed., Sci. and Tech. Series, 6: 1-7.
- KENWARD, R.E. 1987. Wildlife radio tagging. Equipment, field techniques and data analysis. Academic Press, London, 222 pp.
- KNOWLTON, F. & TZILKOWSKI, W.M. 1981. Trends in bobcat visitations to scent-station survey lines in Western United States, 1972-1978. In Blum L.G. and Escherich P.C. (eds.): Bobcat Res. Conf. Proc., Nat. Wildl. Fed., Sci. and Tech. Series, 6: 8-12.
- KOLB, H.H. 1982. Red Fox (Scotland). In Davis D.E. (ed.): Handbook of census methods for terrestrial vertebrates, 231. CRC Press, Florida.
- KOLB, H.H. & HEWSON, R. 1980. A study of fox populations in Scotland from 1971 to 1976. J. Appl. Ecol. 17: 7-19.
- KRUUK, H., GORMAN, M., PARRISH, T. 1980. The use of  $Zn^{65}$  for estimating populations of carnivores. Oikos 34: 206-208.
- KUFELD, R.C., BOWDEN, D.C., SCHIRUPP, D.L. 1987. Estimating mule deer density by combining mark-recapture and telemetry data. J. Mamm. 68: 818-825.
- LAUNDRÉ, J.W. & KELLER, B.L. 1984. Home-range size of coyotes: a critical review. J. Wildl. Manage. 48: 127-138.
- LINDSTRÖM, E. 1980. The Red Fox in a small game community of the south taiga region in Sweden. In Zimen E. (ed.): The red fox. Symposium on Behaviour and Ecology. Biogeografica, 18: 177-184.
- LINDSTRÖM, E. 1982. Age structure and sex ratio of a Red Fox population according to different methods of sampling. Trans. IUGB Congress, 14: 299-309.
- LINHART, S.D. & KNOWLTON, F.F. 1975. Determining the relative abundance of coyotes by scent station lines. Wildl. Soc. Bull. 3: 119-124.
- LITVATIS, J.A. & MAUTZ, W.W. 1975. Energy utilization of three diets fed to a captive red fox. J. Wildl. Manage. 40: 365-368.
- LLOYD, H.G. 1980. The Red Fox. Batsford Ltd. London, 320 pp.
- MACDONALD, D.W. 1980. Patterns of scent marking with urine and faeces amongst carnivore communities. Symp. Zool. Soc. Lond. 45: 107-139.
- MACDONALD, D.W. 1987. Running with the fox. Unwyn Hyman, London, 224 pp.
- MACDONALD, D.W., BUNCE, R.C., BACON, P.J. 1981. Fox populations, habitat characterization and rabies control. J. Biogeogr. 8: 145-151.
- MARTIN, D.J. & FAGRE, D.B. 1988. Field evaluation of a synthetic coyote attractant. Wildl. Soc. Bull. 16: 390-396.
- MAUREL, D. 1983. Movements and space utilization in the fox (*Vulpes vulpes*) as studied by radio-tracking in the forest of Chizé. Proc. Cong. int. fauna cineg. y silv. 15: 421-433.
- MITCHELL-JONES, A.J., JEFFERIES, D.J., TWELVES, J., GREEN, J., GREEN, R. 1984. A practical system of tracking otters *Lutra lutra* using radiotelemetry and  $^{65}Zn$ . Lutra 27: 71-84.
- MONTGOMERY, W.I. 1987. The application of Capture-Mark-Recapture methods to the enumeration of small mammal populations. Symp. zool. Soc. Lond. 58: 25-57.
- NELLIS, D.W., JENKINS, J.H., MARSHALL, A.D. 1967. Radioactive zinc as a faeces tag in rabbits, foxes and bobcats. Proc. 21 Conf. S.E. Ass. Game and Fish Commiss. 205-207.
- NOVAK, M., BAKER, J.A., OBBARD, M.E., MALLOCH, B. (eds.) 1987. Wild Furbearer Management and Conservation in North America. Ministry of Natural Resources, Ontario, 1150 pp.
- OTIS, D.L., BURNHAM, K.P., WHITE, G.C., ANDERSON, D.R. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62, 135 pp.
- OVERTON, W.S. 1971. Estimating the numbers of animals in wildlife populations. In Giles K.H. (ed.): Wildlife Management Techniques. 403-455. Wildlife Society, Washington.
- PANDOLFI, M., SANTOLINI, R., BONACOSCIA, M. 1991. Censimento notturno di Volpe (*Vulpes vulpes*) e Gatto domestico (*Felis catus*) in tre aree campione delle Marche. In Prigioni C. (Ed.): Atti I Simp. Ital. Carnivori. Hystrix, (n.s.) 3: 221-224.
- PATRIC, E.F., SHAUGHNESSY, G.A., WILL, G.B. 1982. A bibliography on wildlife telemetry and radiotracking. Dept. Forest and Wildl. Manag., College of Resource Development, Univ. Rhode Island, 60 pp.

- PELTON, M.R. & MARCUM, L.C. 1977. The potential use of radioisotopes for determining densities of black bears and other carnivores. In Phillips R.L. and Jonkel C. (eds.): Proc. 1975 Predator Symp. 221-236. Montana For. and Conserv., Exp. Stn. Univ. Montana, Missoula.
- PHILLIPS, R.L. 1982. Red fox (U.S.). In Davis D.E. (ed.): Handbook of census methods for terrestrial vertebrates, 229-230. CRC Press, Florida.
- PIGOZZI, G. 1986. Crested porcupines *Hystrix cristata* within Badger setts *Meles meles* in the Maremma National Park, Italy. *Säugetierk. Mitt.* 33 261-263.
- POLLOCK, K.H. 1982. A capture-recapture design robust to unequal probability of capture. *J. Wildl. Manage.* 46: 752-757.
- POLLOCK, K.H., LANCIA, R.A., CONNER, M.C., WOOD, B.L. 1985. A new change-in-ratio procedure robust to unequal catchability of types of animals. *Biometrics* 41: 653-662.
- PRIGIONI, C., TACCHI, F., ARMIRAGLIO, E. 1991. Conteggio delle tane riproduttive di Volpe (*Vulpes vulpes*) in un'area golenale dell'Italia settentrionale. In Prigioni C. (Ed.): Atti I Simp. Ital. Carnivori. *Hystrix*, (n.s.) 3: 215-220.
- PULLIAINEN, E. 1981. A transect survey of small land carnivore and red fox populations on a subarctic fell in Finnish Forest Lapland over 13 winters. *Ann. Zool. Fennici* 18: 270-278.
- PUTMAN, R.J. 1984. Facts from faeces. *Mammal Rev.* 14 79-97.
- RAU, J.R. 1988. Ecología del zorro *Vulpes vulpes* (L.), en la Reserva Biológica de Doñana, S.O. de España. Tesis doctoral, Univ. Sevilla, 265 pp.
- RAU, J.R., BELTRÁN, J.F., DELIBES, M. 1985a. Can the increase of fox density explain the decrease in lynx numbers at Doñana? *Rev. Ecol. (Terre Vie)* 40: 145-150.
- RAU, J.R., DELIBES, M., RUIZ, J., SERVÍN, J.I. 1985b. Estimating the abundance of the Red fox (*Vulpes vulpes*) in SW Spain. XVIIth Congress I.U.G.B., 17-21
- RAU, J.R., DELIBES, M., BELTRÁN, J.F. 1987. Estudio comparado de la dieta de los zorros mediterráneos (Carnivora, Canidae). *An. Mus. Hist. Nat. Valparaíso* 18: 163-168.
- ROBSON, M.S. & HUMPHREY, S.R. 1985. Inefficacy of scent-stations for monitoring river otter populations. *Wildl. Soc. Bull.* 13: 558-561.
- ROLLEY, R.E. 1987. Bobcat. In Novak M., Baker J.A., Obbard M.E. and Malloch B. (eds.): Wild Furbearer Management and Conservation in North America, 670-681. Ministry of Natural Resources, Ontario.
- ROUGHTON, R.D. & SWEENEY, M.W. 1982. Refinements in scent-station methodology for assessing trends in carnivore populations. *J. Wildl. Manage.* 46: 217-229.
- SÁEZ-ROYUELA, C. & TELLERÍA, J.L. 1988. Las batidas como método de censo en especies de caza mayor: aplicación al caso de jabalí (*Sus scrofa* L.) en la provincia de Burgos. *Doñana Acta Vertebrata* 15: 215-223.
- SARGEANT, A.B. 1972. Red fox spatial characteristics in relation to waterfowl predation. *J. Wildl. Manage.* 36: 225-236.
- SARGEANT, A.B., PFEIFER, W.K., ALLEN, S.H. 1975. A spring aerial census of red foxes in North Dakota. *J. Wildl. Manage.* 39: 30-39.
- SCHANTZ, T. von & LIBERG, O. 1982. Censusing numbers of medium-sized nocturnal mammals in open landscapes. *Trans. IUGB Congress* 14:409-415.
- SCHWARTZ, C.C. & BECKER, E.F. 1988. Development of population assessment techniques for lynx. Alaska Dep. of Fish and Game, Project W-22-6, Job 7. 14. Res. Progress Rep., 28 pp.
- SEBER, G.A.F. 1982. The estimation of animal abundance and related parameters. Macmillan Publ. Co., New York, 654 pp.
- SERVÍN, J., RAU, J.R., DELIBES, M. 1987. Use of radio tracking to improve the estimation by track counts of the relative abundance of Red Fox. *Acta Theriologica* 32:489-492.
- SIBLY, R.M. & SMITH, R.H. 1985. Behavioural ecology. Ecological consequences of adaptive behaviour. The 25<sup>th</sup> Symp. British Ecol. Soc. Blackwell Sci. Publ., Oxford. 311 pp.
- SMITH, L.M., BRISBIN, I.L., WHITE, G.C. 1984. An evaluation of total trapline captures as estimates of furbearer abundance. *J. Wildl. Manage.* 48: 1452-1455.
- STEPHENSON, R.O. 1986. Development of lynx population estimation techniques. Alaska Dep. of Fish and Game, Project W-22-2, W-22-3, W-22-4, and W-22-5. Res. Final Report, 84 pp.
- STONEHOUSE, B. (ed.). 1978. Animal Marking. Recognition marking of animals in research. Proc. RSPCA Symp., MacMillan Press Ltd., London, 257 pp.
- STORM, G.L., ANDREWS, R.D., PHILLIPS, R.A., BISHOP, R.A., SINIFF, D.B., TESTER, J.R. 1976. Morphology, reproduction, dispersal and mortality of midwestern red fox populations. *Wildl. Monogr.* 49, 82 pp.

- STUBBE, M. 1980. The Red Fox - *Vulpes vulpes* (L. 1758) - in Europe. In Zimen E. (ed.): The red fox. Symposium on Behaviour and Ecology. Biogeografica 18: 27-34.
- STÜWE, M. & BLOHOWIAK, C.E. 1989. McPAAL (version 2.0). Microcomputer programs for the analysis of animal locations. Users manual, 19 pp.
- TAYLOR, R.H. & WILLIAMS, R.M. 1956. The use of pellet counts for estimating the density of populations of the wild rabbit *Oryctolagus cuniculus* (L.). N. Z. J. Sci. Tech. 388: 236-256.
- TELLERÍA, J.L. 1986. Manual para el censo de los vertebrados terrestres. Ed. Raíces, Madrid, 278 pp.
- TELLERÍA, J.L. & SÁEZ-ROYUELA, C. 1984. The large mammals of Central Spain. Mammal Review 14 51-56.
- TODD, A.W., KEIT, L.B., FISHER, C.A. 1981. Population ecology of coyotes during a fluctuation of snowshoe hares. J. Wddl. Manage. 47: 394-404.
- VOIGT, D.R. 1987. Red Fox. In Novak M., Baker J.A. Obbard M.E. and Malloch B. (eds.): Wild Furbearer Management and Conservation in North America, 378-392. Ministry of Natural Resources, Ontario.
- VOIGT, D.R. & MACDONALD, D.W. 1984. Variation in the spatial and social behaviour of the red fox *Vulpes vulpes*. Acta Zool. Fennica, 171: 261-265.
- WASER, P.M. 1980. Small nocturnal carnivores: ecological studies in the Serengeti. Afr. J. Ecol. 18: 167-185.
- WHITE, G.C., ANDERSON, D.R., BURNHAM, K.P., OTIS, D.L. 1982. Capture-recapture and removal methods for sampling closed populations. LA-8787-NERP, Los Alamos National Laboratory, New Mexico, 235 pp.
- WOOD, J.E. 1959. Relative estimates of fox population levels. J. Wddl. Manage. 23: 53-63.
- ZIMEN, E. (ed.). 1980. Fox social ecology and rabies control. In The red fox. Symposium on Behaviour and Ecology. Biogeografica 18: 277-285.
- ZOELLICK, B.W. & SMITH, N.S. 1986. Capturing desert kit foxes at dens with box traps. Wildl. Soc. Bull. 14: 284-286.